Douglas M. Hudgins

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Erik M. Conway,
Interviewer

Q: My name's Erik Conway. I'm talking to Douglas Hudgins, formerly, the program scientist to the NASA Exoplanet Exploration Program.

Douglas, tell me a little bit about yourself. Where were you born and how were you educated?

Hudgins: I was born in Wyandotte, Michigan, which is a suburb of the city of Detroit. I grew up there, went to college at a small liberal arts college called Adrian College, which is in southeastern Michigan. After graduating with a degree in physics and chemistry, I went on to graduate school in chemistry at Cornell University in Ithaca, New York, and was there and got my Ph.D. in 1990. My Ph.D. is in physical chemistry, but I also had a graduate minor in astrophysics.

From there, I got an offer of a postdoc position with Lou Allamandola in the astrochemistry lab at NASA Ames Research Center in California, moved out there, spent four years in the astrochemistry lab as a postdoc, then actually got a faculty position back at my alma mater, at Adrian College. I taught chemistry at Adrian for three years, but during that time, during the summers I would go back and do research. It was a liberal arts college, so I didn't have summer teaching responsibilities, so I would actually go back to NASA Ames during the summers and continue with the research that we had been doing.

In 1997, I got a job offer, an actual NASA job offer, in the astrochemistry lab, and we moved back to California and I continued our research in the astrochemistry lab. I was there until 2005. I made the terrible mistake that no researcher wants to do, and that is by 2005 or so, basically we had solved the problem that we set out to solve. Now, ideally, as a researcher, you want to solve it at the end of your career so you slide into retirement putting that last manuscript into the mailbox, nailing everything down. So my timing was terrible. I was kind of mid-career at that point. I either had to, like, find a different direction in research or look for something else to do.

At that point, I started to get interested in science management. I took on the branch chief position there in the Astrophysics Branch at NASA Ames, did a detail in the Science Directorate Office at Ames, and then ultimately came to NASA Headquarters for a one-year detail in August of 2005.

After four years of my one-year detail in Astrophysics, they kind of figured out that I wasn't going away, and so it was actually in 2009 that I was hired into the position that I held until just very recently as the program scientist for the Exoplanet Exploration Program. So in addition to other duties as assigned, basically my day job from 2009 until just last year, 2023, was as the program scientist for the Exoplanet Exploration Program.

So it was a pretty amazing time. Maybe I'm getting ahead of myself here, but it was a pretty amazing time, because when I took over as the program scientist for Exoplanet Exploration, we were just preparing to launch Kepler, and when I left that position, now we are basically drafting the plans for the future great observatory, the Habitable Worlds Observatory, that will actually go out and be able to observe and characterize potentially habitable terrestrial planets around other stars. So, just an *enormous* change in the field during the time where I was involved in it as the program scientist.

Q: It's been fantastic to watch as a remote observer too. But I need to take you back to graduate school for a second. What did you work on for your dissertation?

Hudgins: Basically, as a chemist I was really fascinated by the chemistry of space, because in space, the pressures are really, really low and the temperatures are oftentimes really, really low, and so the chemistry that goes on in space is chemistry that the textbooks tell you just doesn't happen, because on Earth you don't do this sort of chemistry. So I used vacuum systems and basically I generated strange small molecules that might exist—in fact, that *do* exist in space—and studied their lifetime, how long they survived and how they fragmented when they fell apart ultimately, and things like that. So it was basically setting strange and weird molecules that exist under the very exotic conditions that exist in the interstellar medium.

Q: And who did you work with?

Hudgins: His name was Richard F. Porter, and he was an established tenured faculty member there at Cornell, had been there for like thirty-five years.

Q: In the Chemistry Department.

Hudgins: In the Chemistry Department, yes.

Q: So one of my questions was, tell me how you came to apply chemistry to astronomy, but it sounds like you started out doing that.

Hudgins: Absolutely. I was an amateur astronomer from the time that I was in high school. I'd built my own telescope. So I was fascinated by space. When I went to college, it was clear to me that I was a much better chemist than I was a physicist [laughs], and so I went into chemistry, but I was always fascinated, as I said, by the chemistry of space and that interface between the two.

I was really fortunate, because the person at NASA Ames, Lou Allamandola I mentioned, at the time that I was looking for a job, Lou had only recently joined the staff at NASA Ames and was looking to build a program to do what we call laboratory astrophysics. That's basically studying analogs in the lab of molecules that exist out in space. So he was really looking for people who knew their chemistry and knew spectroscopy and understood solid chemistry, who also were interested in the application of that knowledge to astrophysics. The timing for me just turned out to be perfect, because at about the time that I was looking for a job, he was looking for me. So it just clicked and it really worked out well.

Q: So you had basically two stints at Ames before going to Headquarters, and I guess you ascended to the level of branch chief after you solved the problem you set out to solve—

Hudgins: Right. [laughter]

Q: —which was too early. What I saw from your online bio, was that PAHs were the chemicals that you were really fascinated by.

Hudgins: Yes.

Q: Tell me a little bit about that.

Hudgins: So PAHs, PH stands for polycyclic aromatic hydrocarbons, and basically they are molecules that are made up of fused hexagonal rings of carbon, and they can be as small as two rings of carbon fused together in the molecule called naphthalene up to very large molecules with hundreds of carbon atoms that are all just a network of these hexagons all put together in different ways. It turned out that when you looked at the infrared spectra of these things, there was a lot of—I started there. Let me take a step back.

At this time in the late 1980s, just before I came on, it was kind of the opening of the door into the infrared. The Kuiper Airborne Observatory at NASA Ames had been flying, and it provided a window on the infrared that you couldn't do from the ground. From the ground, you've got lots of water vapor in the air, and water vapor absorbs *hugely* in the infrared and blocks huge swaths of the infrared spectrum. Well, if put an infrared telescope on an airplane and fly it up at around 40,000 feet, you're above virtually all of the water in the atmosphere and you have a much better window on that part of the spectrum.

When they started doing this and taking spectra of these gas clouds in the interstellar medium, what they saw was this family of infrared emission features that fell at very specific wavelengths. And just like atoms have a very distinctive fingerprint, if you will, pattern of absorptions and emission lines in the visible part of the spectrum, well, molecules have their own fingerprints and patterns of emission and absorption lines in the infrared. So it was really—at the time, it caused a great debate in the scientific community about what is it in space that's causing these lines, because what they found out was you just see them *everywhere*. At all gas and dust regions, at all stages of the life cycle of the interstellar medium, did you find these emission features. So it was clear that whatever this material was, it was all over the place up there in space, so people were really interested in figuring out what it was. And that was when we jumped into the fray, when people were first trying to decide what all this material might be.

As chemists, we looked at the infrared spectrum and we felt like these aromatic materials, these polycyclic aromatic hydrocarbons, were consistent with the sort of spectrum that we were seeing, but the problem was if you took a PAH in the laboratory, just off the shelf—you can buy these things from chemical suppliers—if you take them and you put them in, what you find is the pattern of the intensities of the bands was very different from what we saw out in space. In a laboratory, a PAH that you buy off the shelf and look at in the lab is going to have very strong features around 3 microns, very strong features around 11 to 15 microns in the spectrum, and then smaller features in between in the range from, let's say, 6 to 10 microns, some sort of grass there in that region.

In space, it's just the opposite from that. The 3 microns, it's kind of small, at 11 microns, it's sort of small, and then these bands in the 5 to 10 micron region, really big. So the positions were right, but the intensities were all wrong, so what we thought was you look at the conditions where we were finding these things, a lot of intense radiation from hot stars and things like this. We thought, well, maybe these things are ionized and maybe that changed their spectrum somehow. So we went to work developing techniques in the laboratory that would allow us to generate the ions of these PAHs in the lab so that we could measure their spectrum. Long story short—well, too late, but basically what we found is when you ionize these PAHs, the intensities flip more like what we see in space, and with the bands in the 5 to 10 micron region being much stronger.

So what we did—now, of course, we work for NASA, so we recognized that if you have chemicals formed out in space, it's not going to just be one chemical compound or two chemical compounds. Like I said, this is all sorts of compounds with lots of different rings and things like this. There's lots of different what we would call isomers in chemistry, lots of different isomers in these things that you can have. And so what we did is we spent the better part of the next ten years studying all sorts of different PAHs, looking at different families, different structural features of the molecules, and, in a very rigorous fashion, looking at families and how the spectrum evolves with different modifications to the structure as you get larger and things like that.

We also had a great collaboration with a couple of theoreticians there at NASA Ames, Stephanie Langhoff and Charlie Bauschlicher, who were really at the cutting edge of theory on being able to calculate the spectrum of these large molecules, and so together with us doing the laboratory work and then doing the cutting-edge theory on this, we could then bring the two together, interpret the spectrum, know what was going on in the molecules, and really explain—so it wasn't just, "Hey, look, we've got a spectrum. We hold it up against the interstellar spectrum and it matches." It's like, "We can take these things. We've got lots of different molecules. We can put them together into mixtures that do a great job of matching the spectrum. We can tell what's going on in the molecules, why they're emitting the way they are, and what molecules are dominating, what structures are dominating." So it opened up a whole world of diagnostics to be able to understand those bands in space.

And, of course, at the time we were doing this in the early 2000s, we knew that what we were working toward was providing the data that scientists were going to need when JWST flew. At the time, we didn't know that we would have to wait as long as we did [laughter] to see it, but I'll tell you now that I went to Headquarters in 2005 and I've been doing management stuff and haven't been involved in research since that time, but I have told people since the launch of JWST it's been incredibly satisfying, because the work that is going on now was the work that at the time we knew we wanted to make sure that they had the data that they needed to do this, and a lot of the work that JWST is doing related to PAHs is using the data that we produced in the laboratory over the fifteen years that I was involved in the research there. So it's actually quite satisfying.

Q: Fantastic. So it winds up fifteen years later that all your work becomes useful.

Hudgins: Yes, that's right. I guess if you wait long enough, you know, somebody'll find something to do with your data. [laughter]

Q: Fantastic. So you make a move to Headquarters in 2005 for a one-year detail that turns out not to be for a year. What are you working on?

Hudgins: So at Headquarters I started—basically, most program scientists when they come to Headquarters, they start working on research and analysis programs, so you're working on managing the grant process, right? You get proposals in, you organize a review, you oversee the review, you take the results, you recommend selections to the division director or whoever's going the selecting in that, and you write everything up, and then you send everybody out their money, and you oversee the research, make sure they're getting their work done. So that's what I did for the first couple of years.

After that, I was assigned as the program scientist for the Spitzer Space Telescope, and it was an interesting time for Spitzer because—so it was still in its prime mission at that point, but we knew that the time was coming where the cryogen was going to be exhausted, and so we knew that there was going to be a transition to what we called the Spitzer warm mission, and so we went through a couple of years of prime mission, and then we went through the transition of everything that went on in the mission to make the warm mission. I felt really good about it, because, you know, on the one hand, as you're looking at the mission in normal operations, fully functional, with its cryogens onboard, and you think about while the cryogens are going to go away, and all of the capability that you're going to lose because, like, the long-wave instrument, there was no way it was going to be able to operate anymore because the heat of the telescope itself would just overwhelm it. So, going into that, there's always a sense of sort of loss associated with the transition, but because I was working with these really creative people, really knowledgeable people, the Spitzer team, we actually crafted a warm mission that did just some great science.

Looking back on it now, the Spitzer warm mission was just fantastic, in particular in sort of doing some groundbreaking observations that set the stage for what was to come with JWST. So, again, a lot of work that went on with Spitzer we were able to do that really is important to the observations that JWST is doing now. So in retrospect, it was very successful in taking the observatory, despite the loss of its cryogen, and making it into a really, really valuable scientific instrument, making sure it continued to be a really, really scientifically valuable asset after that point.

Q: Who did you have to convince to keep Spitzer going after the cryogen ran out?

Hudgins: The Astrophysics Division director, because you're always trying to balance the money, right? And so the division director, as the division director should, said, "Hey, you know, you've got this instrument, this infrared telescope, but you're going to lose two-thirds of its capabilities when the cryogen goes away. It costs us *x* million dollars a year to keep it operating. Why should I think that this is going to continue to be worth the money that it costs to keep it going?" So, like I said, we had to work with the mission team, but also with the community through the users panel. They helped sort of identify what's the science use cases that we're going to be able to do, the sorts of things that we'll be able to do, and bring back a case to the division that it's worth the division to continue to invest funds in the mission to keep it going, and we were able to do that.

Q: You said earlier that Spitzer contributed to JWST in some ways. Give me an example of how its observations—

Hudgins: So one of the things that you could do, so in the warm mission, because there was less demand on telescope time because there were fewer instruments available, you could do things like do incredibly deep surveys of a region of space, right? And you've seen, like, the Hubble deep field, but you could do the same thing with Spitzer at infrared wavelengths, the infrared wavelengths you could still work at. A great observatory in its prime mission, you can't take three months of time and stare at a patch of sky. There's too much demand for the time, right? I mean, that's just taking too much time.

For warm Spitzer, you could do that, so you could begin to probe much, much deeper into the infrared sky than had ever been possible before and would ever be possible until JWST came along. So you could do things like, you know, looking at different regions of the sky and evaluating, okay, when JWST comes along, which is going to be the best field for JWST to look at? What's the best places for JWST to look at? And you could sort of use it to identify the key questions that JWST can use, because, of course, as you know, JWST time is incredibly valuable. They get more than a thousand proposals every time they put out a proposal call from people who want to use the telescope. So you want to be incredibly efficient with that telescope every minute you spend observing. You want to know that you're looking at the right thing. So it was able to sort of plow the ground, the space that JWST was going to be able to do, and find the best prospects for the things that JWST was going to be able to do.

The other thing that it was able to do is, of course, in the field of exoplanets. Again, we could do things like take two weeks or a month of Spitzer time and just watch one exoplanet system, and we could take the infrared spectrum the *whole* time around as that planet orbits around its star, and from the time that it's in front of it, where we're basically looking at the dark side of the planet, all the way around to when it is basically just about to go behind the star, in back of the star, where we can see basically the full illuminated face of the planet, and you can just stare at it the whole time, and then you can begin, by sort of slicing that up, you can take spectra of the different phases of the planet and you can begin to suss out things like are there variations across the surface of the planet in the clouds or in the hazes or in the temperature or whatever as it went through its orbit. So it was capable of doing some really, really fascinating exoplanet science, again because you could do large projects that took big chunks of time that you would never—we could never do that sort of thing with JWST right now because there's so much demand for the time. You can't just take a month of JWST time and go off and do something. So that was a luxury that we were able to have that did great science and it also enabled our future observatories, ensured that they were going to do great science as well.

Q: Thank you. Those are a couple of great examples. I guess I've got to get to Kepler soon. [laughter] Tell me how you became involved with the Kepler mission. I know it's awarded in like 2001.

Hudgins: It launched in March of 2009, I guess.

Q: Yes.

Hudgins: Within a year or so—so the person who was the program scientist for Kepler at the time of launch was Padi [Patricia] Boyd, and she was on detail from NASA Goddard. A year or so after launch, she returned to Goddard, and so as the exoplanet program scientist at that point now, I said, "Hey, come on. This is NASA's exoplanet mission here, right?" So I was appointed as the program scientist for the mission, so I got into it in the prime mission. I was carried right through into the extended mission, to within two or three years of the actual end of mission operations.

So through all of the—wow. I mean, it was just an incredible time, because before Kepler launched, we knew of a few hundred exoplanets. They were, by and large, these hot Jupiters, and it was butterfly collecting, and what's more, it was rather competitive butterfly collecting, you know. The people that were involved in doing the research, they were very secretive about their observations and their planets until they announced them, and things like this, and it was a very insular sort of community.

When Kepler came along, it found so many planets so fast that it really changed the field. Everybody, prior to that, had been sort of scraping through their data, trying to find evidence of a single planet. With Kepler, every time we dumped data, you knew there were hundreds of planets in that data in there that people had to find. So it became much less insular. Many people, and particularly a lot of younger scientists, entered into the field, joined with the Kepler science team and did postdocs with the people who were on the Kepler science team and things like this, and suddenly you have this large community of people that are all attacking the data.

At this time, the world was evolving a lot. In 2009, that was about, what, ten, fifteen years after the Internet became a thing, right? And we're still learning how this all works, but I think it's pretty well established that the availability of the Internet has changed the amount of collaboration that goes on in scientific research in just very fundamental ways, right? So exoplanet science, new field, a lot of young scientists getting into it. They come in, Kepler's just downloading data, they're getting data out of a fire hose. There's lot of people working together. Because there are so many people working together, they begin to use more collaboration tools, use the Internet and things like this, and so what emerges is, whereas what was a rather insular community of independent groups who were sort of at various—let's just say they were very competitive with each other, into a community that I think has been just remarkably good at sharing and communicating and collaborating together on finding planets and characterizing planets and things like that. Of course, the luxury was there's *so many* planets, that you weren't worried about "Is somebody else going to find my planet before me?" It's like there's so many planets, that *everybody* can find a planet and there's still more left. So that, of course, always helps to make people less competitive when you have that sort of thing. So that's the way it progressed throughout the mission.

That would have been in about 2010, and we went through the whole process of, you know, at the time that the reaction wheels failed, we knew that we had a problem with a couple of the reaction wheels. One of them failed. We did a lot of hand-wringing about what was going to happen if we lost more, and then ultimately it happened.

Personally, I think the engineering work—I had nothing to do with this; I'm not an engineer—the engineering work that that team, together with their industry partners, did in developing a way to continue the mission after the loss of reaction wheels and do incredible science in its own right as the K2 extended mission, is, I think, one of the great success stories in NASA history. You know, losing reaction wheels, that kills a mission dead, right? I mean, we have examples of that. Kills the mission dead. For them to have been creative enough to find a way to continue to operate the spacecraft and continue to do this incredible exoplanet science, a different approach than what they had been able to do in the prime mission, sure, but to be able to continue to use this billion-dollar mission for another five years or whatever it was after the loss of that reaction wheel was nothing short of genius, in my opinion.

Q: So what were they doing in the K2 mission? I saw some material on asteroseismology, but I didn't get past that.

Hudgins: So with the Kepler Space Telescope, you've got this really wide-field camera, right, that can look at lots and lots of stars all at the same time and stare at them and watch for transits, right? Well, in the Kepler mission, they wanted to stay at the same place in the sky for years at a time, right? Well, they couldn't do that anymore. So in the K2 mission, what they did is they were pointing at fields, fields along the ecliptic plane. Most of the time what they were doing was just surveys of fields along the galactic plane, looking for transits. They would point at the stars, they would download the data, and people could look for planets. The shorter-period planets, they could only stare at a particular field for about ninety days before they had to move the telescope again. So they couldn't do a big long search, but if you can stare—I mean, heck, TESS only stares at a particular piece of sky for a month, right, and then it moves on to the next thing. So if you can stare at an area even for a period of ninety days, you can find transits. You can find planets. So instead of doing the sort of census work that they were doing at the start, like they were doing at the start of the mission, now they were doing more of a survey sort of work where "Okay, now we're going to point at different places in the sky and look for planets and see how many planets we find in these fields."

They were also able to do a couple of neat sort of focus-type experiments where they did what we call microlensing campaigns—actually, Spitzer was involved in at least one of these—where they would set up and they would stare—this was a precursor of the work that will be done with the Roman Space Telescope here in just a few years. When it was the right place in the orbit, you could stare Kepler at the galactic bulge, which is where you want to look for microlensing events. I'm sorry. I should probably say a microlensing event occurs when a star or planet or something passes in front of a background star. Its gravity will lens that star and actually focus it, so it'll cause that background star to brighten really dramatically as the star passes in front of it, and if that planet passing in front of it happens to have a planet around it, the planet does the same thing, only to a smaller effect, because it's smaller, it's got less gravity.

So it did this experiment. We coordinated with ground-based telescopes and with Spitzer and also worked when we would find a microlensing events and things like that, and so we actually did a couple of campaigns that were really sort of test cases of what we'll ultimately do with the Roman Space Telescope here in a few years. So, again, it was one of these cases where you had a really, really powerful instrument in space, which is, wow. I mean, just having a good tool in space is a great thing.

And then they said, "Okay, here's the rules for operating it. Here's how we have to operate it. What's the sort of science that we can do?" So they were able to do some experiments with the telescope that they wouldn't have done in prime mission. If the reaction wheels had continued to work, we would still be pointing at the Kepler field, right? Because that was the right thing to do with it when it was fully functional. When those reaction wheels failed and we could no longer do that anymore, then, again, you have that loss of "Oh, we can't do that mission anymore, but, hey, there's this cool stuff that we can still do." And, of course, that's what came of it, so they got to do some things that you wouldn't ordinarily have been able to do with a space asset like that.

Q: It became an opportunity.

Hudgins: Yes, yes, and K2 has discovered hundreds of planets itself.

Q: Thank you, thank you. What was Kepler's principal accomplishment, in your opinion?

Hudgins: Oh, the demographics. So Kepler was set up to determine the demographics, and in my mind, the flagship—the thing that I tell people that we know now that we didn't know before Kepler is when you go out and night and you look up at the sky, whatever stars you see—in the country, that's a lot; if you're in the city, it's not very many, but whatever stars you see, most, if not all of them, had at least one planet and probably more than that. So that's huge, that just the universe is really good at making planets, and what's more, that it's good at making small planets.

The vast huge, overwhelming majority of the planets we found were planets the size of Neptune in our solar system and smaller. In fact, if you look at the plot of different size bins, the really big planets like Jupiter and that are pretty short, and then these planets the size of Neptune-ish and smaller, things that we call sub-Neptunes and super-Earths, things that are around two times the Earth's radius, two to four times the Earth's radius, you have the most planets in those. Then the abundance seems to fall off as you go to smaller planets like the Earth's size, but that falloff to the smaller planets is due completely because they were hard to detect. So I don't believe that that falloff is actually real. It's either level or it rises even more as you go to smaller planets. It's just we couldn't detect them as efficiently as we could detect those larger ones.

So I think the fact that there are more planets than stars in our galaxy *and* that the vast majority of those planets are relatively small in terms of planetary sizes is hugely exciting, because, of course, what we're interested in ultimately, I think what captures people's imagination with exoplanet exploration is the fact of finding another planet like the one we live on here somewhere out in space, and I think that's the thing that captures everybody's imagination, and that just tells us that, yeah, we haven't found it yet, but, boy, for me, knowing what we know about the distribution of sizes of planets, I simply can't imagine a universe where there aren't other planets like the Earth out there. Now, I'm not saying life or certainly intelligent life out there, but other planets, other terrestrial planets that have the conditions that would be required for the existence of life, I can't imagine a universe where that would not be true.

Q: Statistically it would be improbable.

Hudgins: That's right, that's right, and that's a huge result. I think that's just—yeah, that's as big as it gets.

Q: So to reduce our Kepler story here a little bit, you also become the program scientist for the Exoplanet Exploration Program in about the same time, and that program's new.

Hudgins: Yes.

Q: So talk about why it was set up to start with.

Hudgins: This was sort of a phoenix-from-the-ashes thing. The predecessor to the Exoplanet Exploration Program was NASA's Navigator Program, and if you go all the way back to the late 1990s and early 2000s when Dan Goldin was the administrator, basically he pitched the vision that we needed to find and characterize another Earth, and this was the vision. We had two mission concepts. One was called SIM, the Space Interferometry Mission, and one was called

TPF, the Terrestrial Planet Finder. SIM was to be the first mission in the queue and it was a mission—it didn't use the transit method; it uses astrometry, which is basically measuring the position of a star really, really precisely, precisely enough that if there was a planet going around it, you would actually be able to measure the physical shift of the star, the wobble of the star, on the sky. Then that was going to do the survey of the sky and find the 50 or 100 most promising Earth-size planets out there in our neighborhood, and then TPF was going to be this massive telescope, actually an array of, like, four telescopes, that were going to work together and were going to enable us to actually image and characterize those planets that were found by SIM. So NASA invested a lot of money in technology development and precursor science and things like this in those missions through the early and mid parts of the 2000s decade.

In 2007, 2008, a variety of events conspired to slow things down. Those missions are really expensive. They were big and expensive missions. There were political winds blowing different ways. You know, the fact is that we're a federal agency, and to some extent we operate within the political environment in Washington, and that political environment changes over a period of—choose your number, two, four, six years, whatever, can change. So priorities change within the government, and also we were getting sort of late in the decade and people were saying, "Well, you know, before we commit to these missions, we're going to have a Decadal Survey that comes out in 2010 and will tell us what to do." So for a variety of reasons, the decision was made within Astrophysics to take our foot off the gas and sort of coast to the end of the decade and see what was coming.

In about 2009, they basically deferred TPF into the future, and SIM, they said basically, "Okay, we're going to take a timeout and we're only going to continue if the Decadal Survey comes out and tells us we need to do that."

And it was about the time this all happened that they decided that they were just going to reinvent the program from Navigator. They would call it Exoplanet Exploration. And the reason was that Navigator Program Office was set up to oversee the development of these large missions. Since the large missions had been either deferred or put in stasis for the time being, they needed to develop a different model for the Program Office, because now, in essence, the raison d'être for the Program Office had gone away. So that's why we reinvented the Exoplanet Exploration Program, and our focus was very much, from the outset, on technology development, because it was clear that the ultimate goal of characterizing a rocky planet around a sun-like star some thirty lightyears away requires just incredibly, incredibly advanced technology. So we very much had a focus on technology development. We started this in 2009. We actually had our first technology development Call for Proposals in late 2009.

In 2009, the Decadal Survey came out. They did not recommend going forward with SIM, and basically, as far as the TPF-type mission, they said, "Hey, you know, this technology is really advanced. We're just not convinced that you're there at this point, advanced enough to build this mission. You need to spend the next decade advancing the technologies of this mission and come back to the 2020 Decadal and present it to us and we'll decide whether we're ready to go on to the big mission." So that's what we did.

There's a variety of things that are included in the Exoplanet Exploration Program, but I think the primary emphasis of our program was on developing the what we call starlight suppression techniques that allow you to block out the light from a star and still be able to see the light from a planet that lies just incredibly, incredibly close to it, right next to it. And that's what we did, and I'll tell you that I feel a great sense of accomplishment, in terms of my own career, to have been involved in that process, because, of course, as you know, when the 2020 Decadal

Survey came out, basically they said, “Hey, yeah, we think you’ve got the starlight suppression technologies where they need to go. We think the next flagship mission for NASA should be this Habitable Worlds Observatory.” They didn’t call it Habitable Worlds Observatory, but we’re calling that now, which is the mission that’s going to go out and it’s going to be able to directly image Earth-like planets. So about the time that I took over the program, that’s the goal that we set out to achieve, and we achieved it. So I think it was a great decade, decade-plus that I was involved in the program, and I think we accomplished a lot.

Then, of course, along with that, the program supports the community, supports exoplanet science, and at the same time, Kepler was doing its great work. TESS came along, did its great work. So you’ve got all this excitement in the community, all this work that’s going on in the community, we’re working to support the exoplanet work that’s going on now, we’re doing the technology development that will enable the missions for the future.

It’s been great, and as I said, as I started to say at the beginning, this is, in my whole career in astrophysics, this is just the most exciting field to work in, and the reason for that, or a part of the reason for that is it’s a new field and it’s also a very engaging field, so the proportion of early-career people that have come into the program and are working in the program and you interact with, you go to conferences and stuff like this, it’s a much younger crowd than you typically encounter in other areas of astrophysics. All these new people have brought this incredible energy into the field, and you go to these meetings and you can just feel it in the whole atmosphere of the meeting, the excitement, the creativity, the diversity of the people that are involved. It’s just really, really been a great field. It’s very exciting. And there’s so much to come.

Q: You mentioned starlight suppression technology for the technology development aspect of the Exoplanet Exploration Program, but what else is there? You can't have just been focused on one thing.

Hudgins: Oh, yes, you can. [laughs]

Q: Oh, really?

Hudgins: There's a lot involved. Understand there's a lot involved with that. So basically, broadly speaking, we had two ways of doing the starlight suppression that we'd need. There's basically coronagraphs and what we call starshades. A starshade is basically a big, very precisely-shaped sail, if you will. The formation flies with the telescope way out in front outside the telescope, 50,000 kilometers away from the telescope, and sits in front of the star and blocks the light there so only the light from the planet actually makes it into the telescope.

A coronagraph is a self-contained instrument within the telescope. All the lights comes into the telescope and the coronagraph uses very sophisticated optics to then separate out the light from the star and block it while still letting that light from the planet go all the way through to your detector, where you can look at it. Two different approaches, and each has its own demands. So, for instance, we talk about a starlight suppression technique. If you're doing starshades, you don't just build a big circle and throw it out there in space. You've got to worry about formation flying, because this thing has to be able to align itself up right in front of your telescope and hold itself there at 50,000 kilometers within a few meters of the right position in front of the telescope in order for it to work.

So doing that starlight suppression involves formation flying, and also you need to make sure what's a good material, what's the right shape for the starshade. Turns out it's not a circle; it's a shape like a sunflower shape. You may have seen a picture of a starshade. It has petals, right? What's the right shape for the petals? How do you make the edges of that petal so that they don't reflect light in the telescope? You have to make them really sharp. In fact, it turns out you make them really sharp so they don't reflect and everything like this, and then as you're doing your observations, to kind of average things out, you rotate the thing around.

I used to joke with the folks in the Program Office that we were missing a bet not selling starshades as just calling them starshades, instead of calling them giant space ninja stars [laughter] because that's what it really is. These edges need to be razor blade edges, right? They're incredible sharp and it spins and everything. So we used to joke about that. But when I say, "Oh, we're doing research into starshades," there's a lot that has to go into that.

Then for coronagraphs, it's the same sort of thing. For your coronagraph to work right, it's very complicated optics, and there are different types of optics that can accomplish the same thing, so which optical approach, which optical solution is the best one? So you have to invest in several different designs of coronagraphs to see which one is the one that's going to operate the best.

Since all the light is coming into the telescope and going through your coronagraph, your telescope has to be incredibly stable, much more stable than, like, the Webb Space Telescope is. So you have to figure out how are we going to make a big telescope, a six-meter telescope or something like this, and it's going to be stiff enough that it will allow a coronagraph to work well, to work effectively when we point it at a star.

Coronagraphs involve things that are called deformable mirrors, which—you're nodding, so I assume you know what I'm talking about. They're mirrors that basically have little pistons underneath the surface that can actually change the shape of the mirror very precisely, and basically you figure out if the wavefront coming into the telescope is distorted a little bit because your primary mirror has errors in it—everything it reflects off has errors. Well, you can actually detect that and then suddenly change the surface of this deformable mirror so when you reflect off of it, you've eliminated all those inaccuracies in the wavefront, and that helps your coronagraph work. So think of this more as a large package of things that have to be developed. There's a lot of technologies within each of these that you're working on at any given time. So they're big tasks.

But that's the challenge right there, is the starlight suppression getting to basically to see an Earth-size planet around a sun-like star at thirty lightyears away from us. The planet's light is about ten billion times fainter than the light of the star, so your technique has to be able to throw away ten billion photons from the star without throwing away that one photon from the planet. So it's an incredibly, incredibly demanding, incredibly demanding technological feat. So, yeah, that really was our primary focus for the decade.

Q: I'm out of time. My next question would have been about ground observatories and ground observing, but we may have to reconvene and talk some more.

Hudgins: Sure.

Q: Okay?

Hudgins: Obviously you see that I'm very good at talking, and so it's oftentimes hard to get me to shut up, so if you want to talk again, I'm happy to do so.

Q: I'll set up another appointment for that. You'll get this transcript back first in a week or two. Okay?

Hudgins: All right.

Q: Fantastic. Great talking to you. Thank you.

Hudgins: Thanks. Good to talk to you. Take care.

Q: Take care.

Hudgins: Bye.

Q: Bye.

[End of interview]